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An optimal energy dissipation strategy of the MinCDE oscillator in regulating symmetric bacterial cell division[1]

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Sustained molecular oscillations are ubiquitous in biology. The obtained oscillatory patterns provide vital functions as time-keepers, pacemakers and spacemarkers. Control-theory type models have been introduced to explain how specific oscillatory behaviors stem from protein interaction feedbacks, whereas the energy dissipation through the oscillating processes and its role in the regulatory function remain elusive. Here we developed a general framework to assess oscillator's regulation performance at different dissipation levels. Using Escherichia coli MinCDE oscillator as model system, we showed that, unlike stationary regulators' monotonic performance-to-cost relation, excess dissipation at certain steps in the oscillating process damages the oscillator's regulatory performance. We further discovered that ATP hydrolysis energy has to be strategically assigned to the MinE-aided MinD release and the MinD immobilization steps for optimal performance, and higher energy budget improves the robustness of the oscillator. These results unfold a novel mode that living systems trade energy for regulatory function.

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